INTEGRATED METHODOLOGICAL APPROACH TO THE DETERMINATION OF SOURCES AND GENESIS OF THE BURIED (FOSSILIZED) ORGANIC MATER OF LAKE SAPROPELS

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Determination of sources and genesis of buried (fossilized) organic matter (OM) in stratigraphic sequences of sapropelic lake sediments is a complex task requiring a multidisciplinary research. The study includes a set of special methods and criteria to reveal the OM nature and find a relationship with their sources, which can be autochthonic (water biota) or allochthonic (on land plants). Sources of modern OM in lakes have been investigated in the first stage of our research. The dominant producers of autochthonic OM are autotrophic phytoplankton, periphyton, and macrophytic water plants [Leonova et al., 2014]. Changes of the OM sources were determined by calculation of proportions of remains of different plants and other organisms in the sapropel layers according to [Korde, 1960]. These data is the basis for biostratification of the Holocene sediment sequences and it allowed us to deepen our understanding of the sedimentation environment and the OM origin.

The approach is exampled here by the data of a 3 m long core of the organic sapropel from Lake Ochki (southern Transbaikalia) and 4.4 m long core of the organic-mineral sapropel from Lake Minzelinskoe (south-west Siberia). Biostratification of the sapropel in Lake Ochki (Fig. 1A) indicates mixt OM sources and changeable dynamics of sedimentation of phyto- and zooplankton (autochthonic) and pieces of soil and remains of green (*Drepanocladus*) and sphagnum mosses (allochthonic). The proportion of the autochthonic part recurrently varies from 90 to 40 % in the upper 190 cm of the core and tends to decrease with depth. In the allochthonic part, soil particles are dominant, and their proportion increases with depth. The particles are rather coarse due to the remains of the macerated tissues of the peat-forming angiosperms (mostly grasses and reeds). These data allowed us to conclude that plankton was the main source of the Lake Ochki sapropel during 10.8 kyr of the Holocene. Changes of the proportions of OM sourced from the lake and the land indicate some alternations in the sedimentation environments.

Biostratification of the sapropel in Lake Minzelinskoe (Fig. 1B) also indicates mixt of the OM, nevertheless of different origin. There are remains of semi-submerged and submerged water macrophytes as the autochthonic part and remains of *Hypnum* green mosses as the allochthonic part. The upper 300 cm of the section is macrophytogenic sapropel which gradually changes to peaty sapropel below. The sediment record and its biostratigraphic interpretation suggests a swampy Minzelinskoe basin since ca. 5.9 ^{14}C kyr BP. A humus-rich highly mineralized sediment with a number of mollusk shells formed there in the beginning (core depth of 440-420 cm) represents a shallow lake overgrown by water macrophytes. Then, a true lowland-type swamp dominated by *Drepanocladus aduncus* existed till ca. 4.0 ^{14}C kyr BP. The lake appeared to rise in the interval of 4.-3.2 ^{14}C kyr BP, and the lake sediments formed from the macrophytogenic source since then.

Together with the direct biological estimations of the OM sources, indirect methods are also available. We used several criteria resulted from the organic geochemistry study of the sediments by the pyrolysis chromatography-mass spectrometry: molecular composition of the aliphatic hydrocarbons (*n*-alkanes) and labile components of the protein-carbohydrate compounds [Melenevsky et al., 2012] usually named biomarkers. In the Lake Ochki sediments, products of the polysaccharide decomposition mark the autochthonic phytoplanktonic OM, components of the protein-carbohydrate compounds mark the autochthonic zooplanktonic OM and uneven *n*-alkanes mark allochthonic OM sourced from mosses [Melenevsky et al., 2015, Leonova et al., 2018].

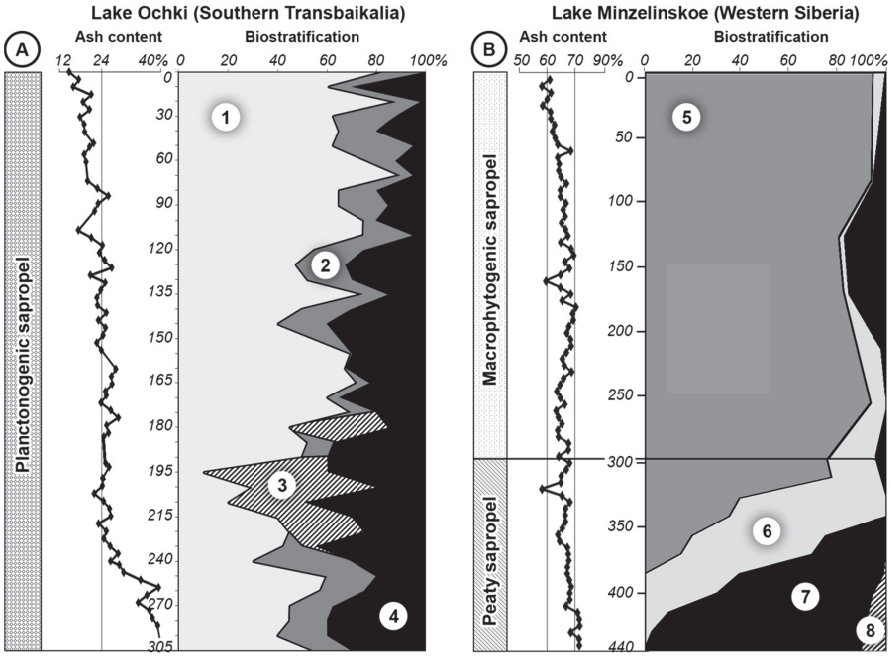

Fig. 1. Biostratification of the Holocene sapropel sediment sequences from Lake Ochki (A) and Lake Minzelinskoe (B). The analyses were done by T.A. Kopoteva (IVEP FEB RAS). 1 – plankton; 2 – green mosses; 3 – sphagnum mosses; 4 –particles of humus; 5 – submerged macrophytes; 6 – hypnum mosses; 7 – semi-submerged macrophytes; 8 – mollusk shells

Figure 2 presents pyrograms of the OM producers and sapropels of our three investigated lakes. The pyrograms have specific peaks: high-temperature peaks (500 C) witnesses presence of the macromolecular aliphatic structures (kerogen considerably reduced due to the anaerobic conditions in the sediments) and several low-temperature ones (300–400 C) witness labile components of the protein-carbohydrate compounds. Comparison of the pyrograms shows that in the sapropel the labile components of the protein-carbohydrate compounds disappear from the depth of 5 cm and kerogen appears. This suggests that decomposition of the OM and generation of kerogen is a very young process which starts in the uppermost parts of the sapropel and can be qualified as the early diagenesis stage. Due to this, only a persistent OM is left in the deeper parts of the sapropel and its further decomposition occurs much slower.

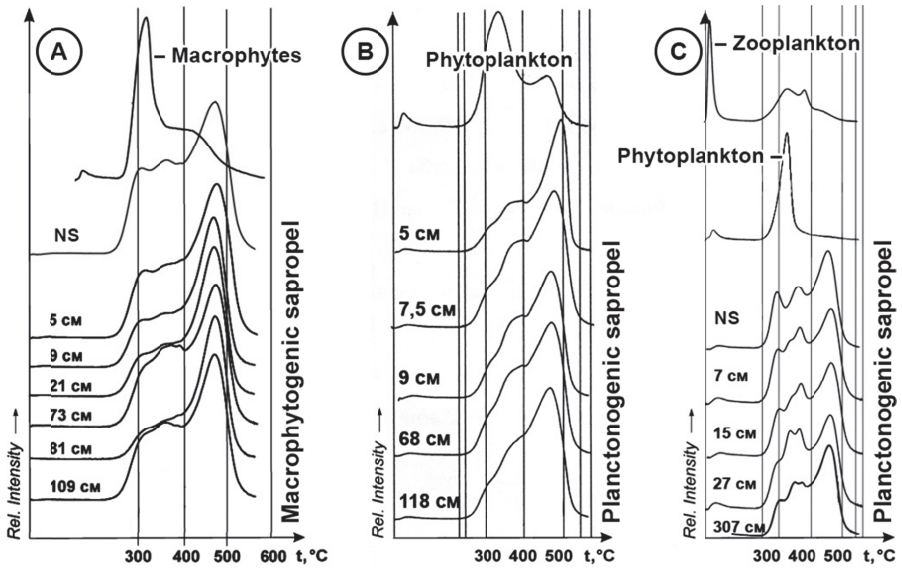

Fig. 2. Pyrograms of the OM poriducers and sapropels of the Bolshoe Toroki Lake (A) (south-western Siberia), Dukhovoe Lake (B) and Ochki Lake (C) (eastern Transbaikalia). NS – nonconsolidated sediment (0–2 cm). Rel. Intensity – rate of the pyrolithic fractionation at a certain temperature.

Besides, the authors used the organic carbon to the organic nitrogen ratio (C_{org}/N_{org}) as additional organic-geochemical indicator. The sapropels of the small lakes of Transbaikalia were found to have the lowest C_{org}/N_{org} ratios (5,7–7,0), which marks the autochthonic phytoplanktonic component of the OM. The West-Siberian lake have higher C_{org}/N_{org} ratios in the sediments and represent both autochthonic (water macrophytes) and allochthonic (mosses) OM sources [Melenevsky et al., 2015; Leonova et al., 2018].

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PALEOLIMNOLOGY INVESTIGATIONS OF THE ANZERSKY ISLAND, THE SOLOVETSKY ARCHIPELAGO, THE WHITE SEA

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A complex study of bottom sediments of lakes on different hypsometric marks allows reconstructing the shoreline moving and environmental changes in the Late Pleistocene and Holocene for the White Sea region. (Subetto, 2009; Kolka *et al.*, 2013). The method of isolated basins is used in the research. The lakes of the Solovetsky Archipelago and Onega Peninsula were investigated in numerous expeditions before (Subetto *et al.*, 2012, Leontev *et al.*, 2015, 2016).

In 2015 paleolimnological field research on the Anzersky Island (the Solovetsky Archipelago, the White sea) were held in the course of complex expedition on board of Northern Water Problems Institute scientific ship «Ecolog». The participants of expedition present Herzen State Pedagogical University (St-Petersburg); Northern Water Problems Institute Karelian Research Centre RAS (Petrozavodsk); Institute of Limnology RAS (St-Petersburg); Geological Institute Kola Science Centre RAS (Apatity), Moscow State University.

The field research included reconnaissance, study of the position of reservoirs, selection and visual inspection of the lakes, specification marks the water's edge and threshold runoff, bathymetric survey, sampling of modern sediments, sampling of selected lakes bottom sediments from the platform with using russian peat corer (for subsequent pollen, diatom, chironomid, grain size analysis, determining the weight of loss on ignition and radiocarbon dating), lithological description of the sediment cores.

With the aim of paleogeographic reconstruction the lakes were chosen at different hypsometric levels: Nadbannoye (21 m ASL), Bannoye (14 m ASL), Golgofskoye (11 m ASL) and Kaporskoye (6 m ASL) (Fig. 1).

The lithological analysis of the Anzersky Island lakes sediments allow to preliminarily attribute limno-glacial, marine, transition and contemporary lake sediments. The first results of the laboratory analysis and radiocarbon dating will be presented at the conference.